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## **Hypermedia As Medium**

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# **HYPERMEDIA AS MEDIUM**

## **Abstract**

This paper describes claims and rebuttals that hypermedia (the associative, nonlinear interconnection of multimedia materials) is a fundamentally innovative means of thinking and communicating: a new medium. Advocates of hypermedia pose several arguments for why this representational architecture is a major advance over other media:

- the associative, nonlinear nature of hypermedia mirrors the structure of human long-term memory
- the capability of hypermedia to reveal and conceal the complexity of its content lessens the cognitive load on users of this medium
- the structure of hypermedia facilitates capturing and communicating knowledge, as opposed to mere data
- hypermedia's architecture enables distributed, coordinated interaction, a vital component of teamwork

However, skeptics argue hypermedia has several intrinsic problems that severely limit its effectiveness as a medium:

- people become disoriented when navigating through large hypermedia structures
- traversing a hypermedia network imposes considerable cognitive overhead on the user
- creating hypermedia structures involves a very large front-end investment of time and expertise
- "Tower of Babel" situations are likely in shared hypermedia systems

Few technological innovations have greater potential to transform society than does a new medium (e.g. the long-term effects of the invention of writing). If hypermedia does transcend its limits to infuse civilization as a new means of thinking and communicating, the consequences will be profound.

## **Introduction**

Since the dawn of civilization, few full-fledged media have emerged as vehicles for thought and interaction. The spoken word, the written word, still images, and full-motion images are the major representational methods that people have evolved to symbolize and communicate ideas. Enthusiasts for hypermedia (the associative, nonlinear interconnection of multimedia materials) are now claiming that a new medium has emerged. If this assertion is true, then a host of direct and indirect consequences for civilization will follow. Few technological innovations have greater potential to transform society than a new medium (e.g. the long-term effects of the invention of writing). This paper describes claims and rebuttals that hypermedia is a fundamentally innovative means of thinking and communicating.

All media except the spoken word have required a technological infrastructure; their advent in history coincided with the development of innovations capable of actualizing such a medium. Full-motion images, for example, were not widespread until a cluster of technological advances in the early part of this century empowered "motion pictures" (both photographic and animated). Hypermedia has not emerged until the present because powerful computers with relatively large memories are needed to create, store, and display large webs of nodes and links. The usage of computers has altered almost every aspect of society; will hypermedia be the next major impact, the first computer-centered medium?

### **Reasons for Excitement about Hypermedia**

Advocates of hypermedia pose several arguments for why this representational architecture is a major advance over other media:

- the associative, nonlinear nature of hypermedia mirrors the structure of human long-term memory, empowering both intelligence and coordination through intercommunication
- the capability of hypermedia to reveal and conceal the complexity of its content lessens the cognitive load on users of this medium, thereby enhancing their ability to assimilate and manipulate ideas
- the structure of hypermedia facilitates capturing and communicating knowledge, as opposed to mere data
- hypermedia's architecture enables distributed, coordinated interaction, a vital component of teamwork, organizational memory, and other "group mind" phenomena

The intuitive case for each of these arguments is presented below; the section following describes reasons for skepticism about these claims.

*Hypermedia is Associative and Nonlinear:* Human long-term memory is not similar to a computer database; remembering something does not involve doing a pattern-matching search through large numbers of records. Instead, the information a person assimilates is organized into an elaborate web of associations. For example, the term "apple" conjures up connotations of pies, orchards, Isaac Newton, the Beatles, the Garden of Eden, and a computer corporation—all interrelated through an correlational network. Our adeptness in quickly storing and retrieving large amounts of information seems to stem from this property of associativity (Caudill, Butler, 1990).

One of the most important subdisciplines in artificial intelligence is knowledge representation. This field centers on devising formalisms that allow a computer's logical mechanism to access and manipulate knowledge (a more complex entity than data, as will be discussed later). Some of the most useful representational architectures researchers in this area have developed—frame-based expert systems, object-oriented databases, semantic networks, and hypermedia—all share the property of associativity.

From a different intellectual perspective, biological researchers are studying neural networks (the physiological infrastructure underlying associative memory) to determine why organisms have such powerful abilities to recognize complex patterns and to learn. This work is generating insights about how simultaneous, distributed processes can be coordinated through intercommunication. From these studies of associative physiological networks, many applications are emerging in fields ranging from manufacturing to cognitive science. Research from these multiple perspectives suggests that associativity is fundamental to both intelligence and to coordination via communication.

Hypermedia is much more associative than traditional media because of its nonlinearity. Spoken and written speech, still and full-motion images are all linear media: each conveys a sequential stream of data. Packets of information based on these media have a beginning, a middle, and an end; authors seek to find a single logical flow that expresses the totality of ideas they wish to communicate to their audience. Each concept is locationally associated only to those ideas preceding and following it in the linear stream.

In contrast, nodes in hypermedia can have an arbitrarily large number of direct associations (links) to other concepts. This flexibility is valuable in generating and communicating ideas. For example, divergent thinking (e.g. brainstorming) is difficult to capture when the ideas must be summarized convergently in quasi-linear form (i.e. a hierarchical outline). Mental models have richer associations than can be represented by the "tree" of correlations a hierarchical structure can express; hypermedia provides a formalism that can depict this complexity.

As another illustration, recontextualization (seeing a phenomenon from a variety of perspectives) is a powerful approach to problem solving. Using this approach requires a medium capable of simultaneously representing multiple mental models (in the same way that a two-dimensional optical illusion can be interpreted as different solid objects, depending on the virtual orientation selected by the viewer). Hypermedia's flexibility as a representational formalism facilitates recontextualization; a web, for example, can be conceptualized via analysis (as a set of nodes) or synthesis (as a network of links). The combination of associativity and nonlinearity in hypermedia adds dimensions to thought and communication lacking in other media.

*Using Hypermedia Lessens Users' Cognitive Load:* Because hypermedia mirrors the representational architecture of long-term memory, assimilating and communicating thoughts in this format may require less internal preprocessing. The effort involved in translating to and from an associative intellectual structure is eliminated. For example, authors can develop writer's block even when they know everything they wish to express. Part of the problem may be the challenge of mapping long-term memory's associative web of relationships into a linear stream. Hypermedia could serve as an external, virtual mirror for a person's memory: A writer could follow

different trails through a web instantiating his knowledge until he found the best linear path to express the ideas in his document.

Beyond this, hypermedia seems a powerful approach for revealing and concealing complexity when analyzing a phenomenon. As an illustration, abstraction is an important cognitive strategy, but thinking abstractly involves rapidly shifting among different levels of specificity. Problem solving often requires moving from an overall perspective through increasing amounts of detail until an insight occurs and a subproblem less complex than the total situation is mastered. Then this understanding is generalized, as much as possible, to test its utility in comprehending other aspects of the problem.

Hypermedia can empower this type of intellectual process by providing ways to represent and navigate through complex levels of abstraction. Detail can be concealed until needed, then revealed by activating a link. A node, when viewed at a greater level of specificity, can reveal a subnetwork of nodes and links as its internal structure: webs embedded within webs. Attempts to create similar representations in the medium of paper generate a useless spaghetti of lines.

People using hypermedia report that this medium seamlessly interconnects its contents. Creating regularities in the menu structure of different tools on a computer is an important design strategy; users want the same commands to activate the "delete" function whether they are working with a word processor, a database, or a spreadsheet. In the same manner, consistency across the interface between the thinker and the subject of thought reduces cognitive load. The multiple representational formalisms hypermedia supports are all accessed in the same manner (activate a link). This ease of use stands in sharp contrast to a person juggling an atlas, a database of still images, an encyclopedia, a cassette tape, and a videoplayer to acquire information.

#### *Hypermedia Facilitates Capturing and Communicating Knowledge:*

Because of its associativity and low cognitive load, hypermedia is an attractive representational architecture for knowledge bases. "Data" can be defined as input gathered through the senses, and "information" as a pattern of input that signals an important change in the environment. In this schema, "knowledge" is integrated information that can be used to achieve a goal. To illustrate these definitions, learning that a new type of workplace tool exists would be data, realizing that it could add valuable functions to the one's occupational repertoire would be information, and mastering the tool would be knowledge.

Past generations of information systems have used advances in hardware and software to augment users' access to data, on the assumption that individual and institutional knowledge would thereby increase. After several decades of advances in data processing, however, even personal computers can deliver so much information that their users become overwhelmed: unable to decide which data is important or to interconnect new information with

existing knowledge. Researchers in artificial intelligence believe that future information systems will use emerging increases in power not to create faster and larger databases, but instead to deliver "knowledge bases": contextually targeted, associationally interconnected data with embedded computational inferencing mechanisms (Brodie, Mylopoulos, 1986).

An interesting metaphor for knowledge processing is the concept of "cyberspace," a term that originated in a science fiction novel (Gibson, 1984). Cyberspace would be a real-time, online, multi-person virtual world in which, through ideas from scientific visualization, cognitive entities would take on tangible, sensory form to facilitate access and manipulation. This idea has captured the imagination of researchers in human factors, scientific visualization, gaming, computer-aided design, architecture, artificial intelligence, virtual realities, networking, computer-supported cooperative work, and hypermedia.

The design of cyberspace environments for depicting knowledge poses many research issues (Benedikt, in press). These include the costs and benefits of reifying information, space-time axiomatics in artificial realities, magic versus logic as principles underlying user actions, the presentation of the self in a virtual context for group work, the meaning of travel and action when translated from a physical to a symbolic domain, coordinate systems for (un)real estate, the form and meaning (semiotics) of data objects, three-dimensional user interface design, visual languages, alternatives to a spatiotemporal metaphor for virtual reality, and the architecture of multi-dimensional data spaces. (An entertainment-oriented cyberspace would create a different set of challenges—its users could interact, go on shared adventures, get married or divorced, start businesses, found religions, wage war, hold elections, construct legal systems, tailor their virtual physical appearances, and assume alternative personal identities and interpersonal styles.)

Developers of cyberspaces are using hypermedia as their representational structure; no other medium can support the complex knowledge architectures required. Similarly, knowledge base research is focussing on associative formalisms, such as hypermedia, because interrelation seems central in transforming information to knowledge. An illustration of the importance of associativity is the encyclopedia: civilization's attempt to encapsulate the total span of knowledge.

The chunks of data that are interrelated in an encyclopedia (a linear medium) are only those in the span of a single article; this segmented approach captures a small fraction of the total knowledge of the articles' authors. For example, to comprehend the role in history of the year 1842, one would have to scan every paragraph in the encyclopedia for events related to that period, then try to make sense of this jumble of data. A hypermedia-based encyclopedia, in contrast, could support webs of knowledge stretching across the full spectrum of articles: One could contrast an economist's perspective on the causes of the American Civil War with that of a slave or of an abolitionist. An associative

encyclopedia can represent multiple mental models for interpreting the same data: alternative knowledge structures.

*Hypermedia Enables Distributed, Coordinated Interaction:*

Hypermedia may make knowledge easier to communicate as well as easier to represent. In the emerging field of computer-supported cooperative work (less formally known as "groupware"), many researchers are using hypermedia as the representational formalism for their projects. Applications in computer-supported cooperative work (CSCW) center on seven themes:

- building shared mental models
- aiding group design and decision making
- developing machine-based organizational memories
- coordinating complex, multi-person tasks
- enabling collaboration despite barriers of distance and time
- reducing Information overload in organizations
- enhancing psychosocial interaction in machine-mediated communication.

Hypermedia's capabilities to capture and communicate knowledge—coupled with its low cognitive load—make it an excellent representational medium for these CSCW applications.

For example, the correlational nature of hypermedia is valuable in building organizational memories. Complex, long-term projects necessitate institutional knowledge bases that transcend the involvement spans of individual personnel; otherwise, important information is lost when people leave, retire, shift to another project, or simply forget. Hypermedia-based associative memories can recall information even when queries are incomplete or garbled, can store data in a distributed fashion, can detect similarities between new inputs and previously stored patterns, and do not degrade appreciably in performance if some of the memory's components are damaged. These characteristics are very useful for a distributed, shared organizational knowledge base.

Educators also are finding that hypermedia can aid in coordinating learning and communicating knowledge. Dede (1990) describes how hypermedia-based applications from CSCW are changing the field of distance learning: The distributed, simultaneous processes underlying distance education can be orchestrated more effectively, and hypermedia's structure makes knowledge easier to transfer across barriers of distance and time.

Wenger (1987) has evolved a theory of knowledge communication, which he applies to artificial intelligence work on intelligent tutoring systems. Making knowledge communicable (the cognitive essence of instruction) requires many of the attributes hypermedia offers: easy translation into long-term memory, consistency across the interface between learner and subject matter, revealing and concealing complexity, support for multiple mental models, associativity. From the perspectives of both work and education,



hypermedia seems a promising communications medium for distributed, coordinated interaction.

### **Potential Limits for Hypermedia**

With all these potential advantages, enthusiasts argue, the world should become "hyperimmediated" as quickly as possible. However, skeptics argue hypermedia has several intrinsic problems that severely limit its effectiveness as a medium (Dede, et al., 1988). The major concerns currently being voiced about hypermedia are:

- people become disoriented when navigating through large hypermedia structures
- traversing a hypermedia network imposes considerable cognitive overhead on the user
- creating hypermedia structures involves a very large front-end investment of time and expertise
- "Tower of Babel" situations are likely in shared hypermedia systems

The intuitive case for each of these arguments is presented below; the next portion of this article summarizes the extent to which research supports these concerns.

Information that is organized in a complex manner poses a potential problem of user disorientation. In a linear medium, one can readily evaluate the extent to which a document's information has been traversed (how many pages read, how many left) and where a particular piece of data is located (chapter, section, paragraph). Large hyperdocuments may be more confusing. In a web of thousands--or millions--of nodes, how does one define a location in the network, establish a desired direction to move, or blaze a trail indicating those nodes already scanned? In a non-hierarchical structure, what type of coordinate system should be used to indicate where a piece of data has been stored? These problems of navigation and referencing are very challenging for networks with large numbers of nodes and links.

Even if a user familiar with a particular network experiences no disorientation, working in a hypermedia knowledge base entails some extra cognitive overhead. When entering material, an author must think carefully about how to link the information being added to the web which already exists. At each node they encounter, users must choose which link to follow from multiple alternatives and must keep track of their orientation in a complex multidimensional structure. The richness of a nonlinear representation carries a risk of potential intellectual indigestion, loss of goal directedness, and cognitive entropy. Unless a hypermedia system is designed carefully from a human factors perspective, increasing the size of the knowledge base may carry a cost of decreasing its usability.

The availability of multiple types of representations in a hypermedia system compounds this problem. Access to representational alternatives allows

users to tailor input to their individual cognitive styles and enables authors to choose a format well suited to the material being entered. However, coping with multiple formats adds to cognitive overload, and little is known about which representational ecologies are functional for different task situations.

The large front-end investment in time and expertise required to author a large hypermedia structure is another type of potential limit. The challenges involved can be illustrated by considering the simple situation of adding a new node to an existing web. The number of links generated by adding an additional node to a network will vary depending on the type of knowledge being stored, the objectives of the documentation, and the sophistication of the user population.

Suppose that many vital, subtle interrelationships exist in the network's material. Although some new nodes will simply annotate single existing nodes, a substantial proportion of nodes that are added may require multiple links. In a million node web with 0.1% of the material interrelated, adding a single new node would require constructing one thousand. The difficulties of comprehending and maintaining such a web could exceed the benefits that a nonlinear medium provides.

One strategy for solving this problem is to aggregate subnetworks into composite nodes that chunk material on a higher level of abstraction: webs within webs. Such an approach is being explored in second generation hypermedia systems—but creating another dimension of hierarchy complicates the representational architecture and, unless implemented in a manner transparent to users, may increase disorientation and cognitive overload.

These potential limits are particularly acute in online, shared hypermedia systems. The user of a collegial electronic knowledge base may find that, since last entering the system, familiar paths have changed and new material has appeared. Links that seem intuitively obvious to the author adding them may be puzzling to others. Skeptics argue that "Tower of Babel" situations are likely with a large knowledge base in which multiple users can alter the fundamental medium of interaction.

Possible problems of disorientation, cognitive overhead, front-end investment, and collective communications dysfunctions reflect the intricacy of working with a knowledge base rather than a database. Knowledge is intrinsically complex, and transforming information to knowledge involves gaining a goal-directed, contextual understanding of the application domain. Utilizing an underlying representation based on hypermedia will require more sophisticated skills--a new type of "literacy"--from its users. Many are skeptical that the benefits of hypermedia will justify the costs of creating this hyper-literacy.

## **Conclusion: The (Hyper)Medium and the Message**

Any medium shapes its message (and the recipient of that message). For example, the imagination and involvement of a child are engaged in different ways when reading a fairy tale in a book than when watching a movie depicting that story. The general question of how the medium shapes the message is emerging as a central issue for information technology research (Dede, in press).

For example, the primary goal of the discipline of telecommunications has been to improve the transmission capabilities of the various media while lowering their cost. Research has centered on technical issues underlying the electrical or optical transfer of information at a distance, irrespective of the content being conveyed. While the challenge of transferring signals reliably and cheaply is still an important theme, now the emphasis in studies of communications media is refocussing on how to extend a state of awareness and related intentions over a distance to others. The importance of this research for understanding the evolution of human thought and communication can be highlighted by describing two illustrative issues emerging in workplace and community settings.

In business, information technology is now seen as an effective method for improving worker productivity and for enhancing an organization's ability to respond quickly and flexibly to environmental changes. These gains are intrinsically accompanied by a decrease in face-to-face interaction and an increase in technology-mediated communication. Workers progressively have more and more colleagues with whom they exchange information, but their primary form of contact is through the telephone or electronic mail.

As a result, the psychosocial aspects of work are changing in complex ways that depend in part on the implementation strategy used to create the institution's information infrastructure. In general, people feel more productive, but less personally fulfilled by their work environment. The consequences of this shift for both workers and organizations are being studied, but our current understandings are very limited, and how the evolution of hypermedia might affect this situation is unclear.

The potentially troubling effects of using advances in technology, such as hypermedia, to mediate human experience are nowhere more clear than in today's community. The single greatest experiential input for many people is the pervasive sensory, informational, and normative environment created by television, radio, videogames, movies and videotapes. In this situation, people's knowledge and values can be constrained by the characteristics of these communications channels.

For example, concerns about "reality pollution" in the news media are mounting. Businesses produce and distribute self-serving, sometimes biased "docutainments" that the media broadcast to cheaply augment their programming. Images can now be doctored electronically to the point that their

authenticity can no longer be determined. Political events are routinely followed by commentaries in which "spin control" experts attempt to skew viewers' perspectives on what they saw.

The cultural consequences of technology-mediated physical/social environments are mixed. On the one hand, people have a wider range of vicarious experience and more contact with specialized human resources than they could attain through direct interaction in their local region. On the other hand, to the extent that perceptions of family life come from situation comedies, of crime from police shows, and of sexuality from soap operas—and to the degree that physical exercise is confined to pressing the buttons on videogames—civilization is in serious trouble.

The technologies themselves do not dictate content that creates a "couch potato" mentality or implies all of life's problems can be solved in thirty minutes. As pervasive interpreters of reality, the media are influenced primarily by economic, political, and cultural forces. But, given that the medium does intrinsically shape the message, society must consider the extent to which communications technologies have generated passive, narcotic behavior for many of its members.

The factors that have created this situation and the potential impact of hypermedia on its dynamics are largely not understood. If hypermedia does transcend its limits to infuse civilization as a new means of thinking and communicating, the consequences will be profound.

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